Broadband Radiation and Scattering

Electromagnetic phenomena are a central thread through much of modern engineering. There are two fundamental classes of applications: open region problems (where the energy propagates in unbounded space) and closed region problems (where the energy is guided by a waveguide structure or cavity).

This effort strives to enhance our computational electromagnetics (CEM) capability in broadband radiation and scattering in open regions. Broadband fields consist of energy with a robust spectrum, and include applications such as electromagnetic interference and electromagnetic compatibility noise analysis, broadband radar, and accelerator wakefield calculations.

LLNL analysis codes are limited by the accuracy of radiation boundary conditions (RBCs), which truncate space. We will develop improved RBCs by extending the perfectly matched layer (PML) approach to non-Cartesian meshes, and by developing discrete-time-domain, boundary-integral techniques, which are compatible with high-accuracy, finite-element methods and capable of arbitrary accuracy. We will compare the two approaches for accuracy and efficiency for a variety of radiation and scattering problems.

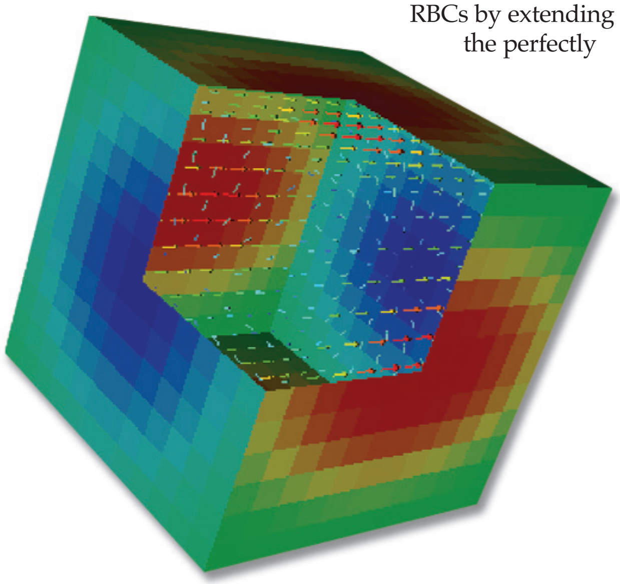

Figure 1. Full hybrid solution for a dipole radiating from the interior of a cube, including surface contours of the magnitude of the electric field together with vectors of the interior field.

Project Goals

The ultimate deliverable is an enhanced CEM capability that can provide accurate and efficient computational solutions to broadband radiation and scattering problems. The algorithms for improved RBCs will be incorporated into LLNL's existing EMSolve code. The result will be a 10- to 1000-fold improvement in the accuracy of simulations. Improved algorithms and our existing high-performance computer hardware will place LLNL's CEM activity among the top capabilities in the world. This research and the resulting capability will be documented in appropriate peer-reviewed publications.

Relevance to LLNL Mission

Electromagnetics is a truly ubiquitous discipline that touches virtually every major LLNL program. Our work supports the national security mission by reducing the time and money spent in building and testing existing programs. It will enable computer simulations for new devices and systems, performance analysis of systems critical to nonproliferation efforts, and the design of micropower impulse radar and other microwave systems.

For more information contact
Robert M. Sharpe
(925) 422-0581
sharpe1@llnl.gov

FY2005 Accomplishments and Results

Figures 1 to 4 are sample results for our FY2005 CEM work. We have completed the initial development for the full parallel hybrid finite-element boundary element code. We have validated the basic parallel algorithms and made comparisons with less accurate ABC boundary conditions. We have collaborated with a professor at the University of Washington, an expert on time-domain integral equations. Several stability issues have been addressed and better quadrature techniques have been developed and implemented. Several research papers have been submitted for publication and results have been presented at national conferences.

Related References

1. Fasenfest, B., D. White, M. Stowell, R. Rieben, R. Sharpe, N. Madsen, J. Rockway, N. Champagne, V. Jandhyala, and J. Pingenot, “Differential Forms Basis Functions for Better Conditioned Integral Equations,” *Antennas and Propagation Society International Symposium, IEEE*, **4 A**, pp. 292- 295, July 8, 2005.

2. Pingenot, J., C. Yang, V. Jandhyala, N. Champagne, D. White, M. Stowell, R. Rieben, R. Sharpe, N. Madsen, B. Fasenfest, and J. Rockway, “Surface Based Differential Forms,” *IEEE/ACES International Conference on Wireless Communications and Applied Computational Electromagnetics*, April 3-7, 2005.

FY2006 Proposed Work

The main effort in FY2006 will be to improve the computational efficiency of the hybrid code by developing and implementing fast algorithms for the boundary element solutions. We will continue collaboration with the University of Washington. Filtered Green’s functions, FFTs and QR fast solvers are under consideration. We will also compare the new hybrid code results with results from our previously developed high-order PML boundary conditions.

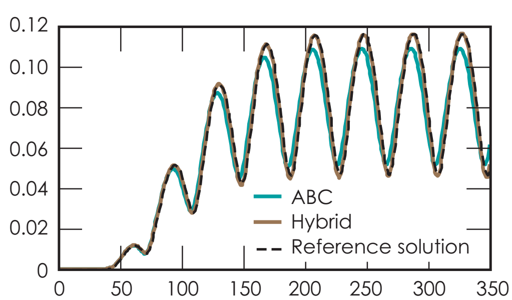

Figure 2. Hybrid solution and ABC boundary condition solution compared with the reference solution, for a plane wave scattering from an interior cubical box. Note that the hybrid solution is significantly better.

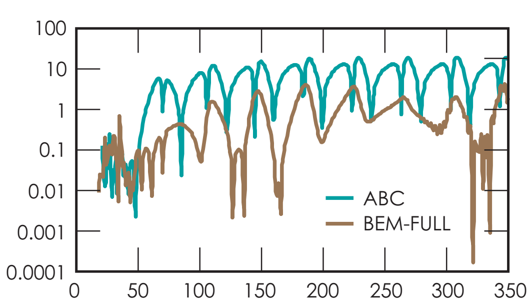

Figure 3. Relative percent error of the full hybrid solution compared to the solution obtained using hybrid and ABC boundary condition solutions. Again, the hybrid solution is better.

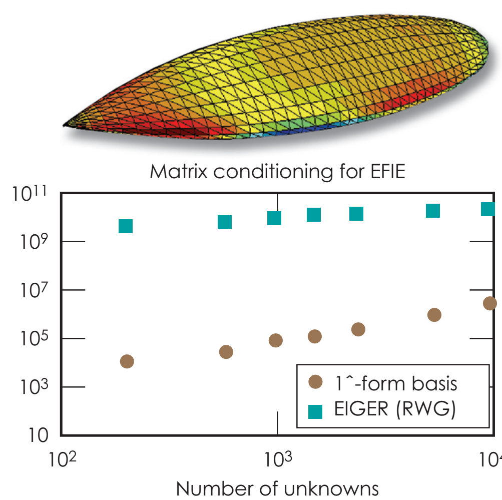

Figure 4. Unexpected results: We have found dramatic improvement in the matrix conditioning for the NASA almond problem when our differential forms bases and nonuniform spectral basis functions.